

Eletromyography of abdominal muscles in different physical exercises

An update protocol for systematic review and meta-analysis

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Abstract

Background: The abdominal muscles are extremely important because they are directly involved in the functions of support, containment of viscera, and help in the process of expiration, defecation, urination, vomiting, and also at the time of childbirth. Many exercises and equipment are used to strengthen the abdominal muscles, and the workouts are proposed for a variety of purposes, such as preventing and rehabilitating low back pain, improving sports performance, achieving aesthetic standards, among others. Exercises that potentiate the electromyographic activity promote a greater recruitment of muscle fibers and are more effective to improve or maintain of the force. The electromyographic activity analysis allows us to reflect on the quality of the exercises proposed, consequently, to choose and order the exercises properly in a training session.

Methods: Our systematic review protocol will developed following the reporting items for the systematic review. To identify relevant studies, we sought articles on the following bases: MEDLINE, PubMed, Europubmed, SciELO, Physiotherapy Evidences Data Base (PEDro), Cochrane, and Google Scholar. The methodological quality of the studies included in the review will evaluated using a checklist and quality assessment. For intervention studies, risk of bias will estimated using the Cochrane Collaboration tool.

Results: The results of this study will show the electromyographic activation of the abdomen in the different types of exercises.

Conclusion: Ethics approval was not required for this study because it was based on published studies. The results and findings of this study will be submitted and published in a scientific peer-reviewed journal.

Systematic review registration: PROSPERO CRD42018086172.

Abbreviations: LRA = lower rectus abdominis, MIVC = maximal voluntary isometric contraction, PRISMA -P = preferred reporting items for systematic review and meta-analysis protocols, RA = rectus abdominis, RCT = randomized clinical trial, RMS = root mean square, URA = upper rectus abdominis.

Keywords: abdominal exercises, electromyography, EMG, exercises, MIVC, rectus abdominis, RMS, strength exercises

Study status: In study selection process.

Authors' information: Not applicable.

Competing interests: The authors declare that they have no competing interests.

Consent for publication: Not applicable.

Ethics approval and consent to participate: Not applicable.

Availability of supporting data: Not applicable.

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Forces and limits of study of this study.

This study will evaluate the efficacy and safety of abdominal exercises and their effect on electromyographic activation. Two reviewers independently perform data extraction and the risk of bias evaluation. The evaluation system, development, and evaluation of rating advice and further evaluation for further study findings.

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1. Background

The abdominal muscles are extremely important because they are directly involved in the functions of support, containment of viscera, and help in the process of expiration, defecation, urination, vomiting, and also at the time of childbirth.^[1]

The importance of the rectus abdominis muscle in the normal posture of the pelvis is emphasized. Besides that, it is an indirect responsible for the lumbar curvature and of great importance in the posture of the body.^[2] A weak abdomen causes several disorders associated with posture (such as ptosis or low back pain), respiratory disorders, and others.^[3]

Exercises aimed to abdominal strengthening have been practiced, as they involve not only aesthetic goals, but also the prevention and/or rehabilitation of low back pain, improvements athletic performance, increase resistance, and strength of the torso for daily activities, and others.^[4,5]

The higher the electrical activity of the muscle, larger amount of fibers recruited, and improves strength.^[6,7] Exercises that potentiate the electromyographic activity impose greater challenges on the neuromuscular system, therefore they are more effective for the improve the force capacity.^[8]

The hypothesis is that there is a difference in muscle activity observed through the electromyographic values for the rectus abdominis muscle when comparing different exercises proposed to improve abdominal force, performed with and without the use of apparatus.

2. Objectives

This systematic review aims to analyze the activation of the abdominal muscles (rectus abdominis) according to results obtained through electromyographic analysis during the execution of different physical exercises.

3. Methods/design

Our systematic review protocol was developed following the reporting items for the systematic review. The review protocol was recorded in the International Prospective Review Record (PROSPERO) (registration number: CRD42018086172). This study will not involve any private patient data; ethics approval was waived (see online supplementary file 1 for PRISMA-P checklist).

3.1. Study design

This is a systematic review and meta-analysis protocol of prospective cohort studies, following the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analysis protocols) guidelines.^[9,10] The systematic review and meta-analysis will be reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline.^[11] The whole process of study selection is summarized in the PRISMA flow diagram (Fig. 1).

3.2. Inclusion/exclusion criteria

3.2.1. Types of studies. Experimental, cross-sectional studies, case studies, observational studies, and randomized clinical control (RCT).

3.2.2. Type of participants. The inclusion criteria were: studies conducted with healthy humans; population with age limit (18–60 years); trained and familiar subjects in the respective exercises

studied. No restrictions of gender, ethnicity or socioeconomic status shall apply. The exclusion criteria are: studies performed with subjects presenting factors that may interfere with the reliability of the results sought, such as: pregnancy, fracture/displacement, osteoporosis, spine with malformation, skeletal deformities (e.g., Scheuermann kyphosis, scoliosis), leg length discrepancies, spondylitis/spondylolysis, rheumatic disorders (e.g., ankylosing spondylitis, rheumatoid arthritis), equine tail syndrome, abdominal surgery, infection, tumor, infection and systemic/cerebrovascular disease/neuromuscular diseases, heart disease, neurological dysfunctions, alcoholism, smoking, myopathies or neuromyopathies, low back pain, pain in the abdominal region, or any other type of clinical problem that could interfere in the execution of the exercises.

3.2.3. Type of intervention. We will include interventions that investigated the electromyographic activation of the rectus abdominis muscle (RA), independently of its part, being URA (upper rectus abdominis) or LRA (lower rectus abdominis), also studies that present a percentage of maximal isometric contraction (% MVIC) and studies that performed the analysis of the electromyographic signal in the temporal domain.

3.2.4. Types of measures of results. Types of studies that report the results of the percentage of maximal voluntary isometric contraction (% MVIC) and the analysis of the electromyographic signal in the temporal domain on the abdominal muscles in different types of physical exercise will be considered. Studies considered as outcome variable: do not evaluate the % MVIC, RMS or that do not study the electromyographic activation or that did not analyze the EMG signal in the time domain of the rectus abdominis muscle will be excluded. The data collection tools will include analysis of the results obtained through the use of the electromyograph in the exercises performed.

3.3. Search sources

3.3.1. Electronic search. To identify relevant studies, the following electronic databases will be searched: MEDLINE, PubMed, Europubmed, SciELO, Physiotherapy Evidences Data Base (PEDro), Cochrane, Google Scholar. After analyzing the main studies and considering recommendations from specialists, the following keywords were identified for the study: MIVC, RMS, Rectus Abdominis, EMG, Electromyography, Strength Exercises, Abdominal Exercises, and Exercises (Table 1). Three authors will analyze the title and abstract of the articles found. Reference lists of relevant studies will be examined further for other potential studies to be included.

3.4. Data collection and analysis

3.4.1. Data management. Duplicate articles will be removed, and the references evaluated for eligibility will be sorted alphabetically, according to the names of the first authors.

3.4.2. Selection process. Two authors (TMF and FFRB) will independently analyze the titles and abstracts of studies identified by the research strategy. Potentially eligible studies will be re-evaluated by reading the full text. In case of disagreement, the opinion of a third author (FBL) will be requested. Following the guidelines (PRISMA-P), a flow diagram will illustrate the study selection process.

3.4.3. Data collection process. The data will be extracted in ad hoc tables (Table 2). An author (TMF) will complete the

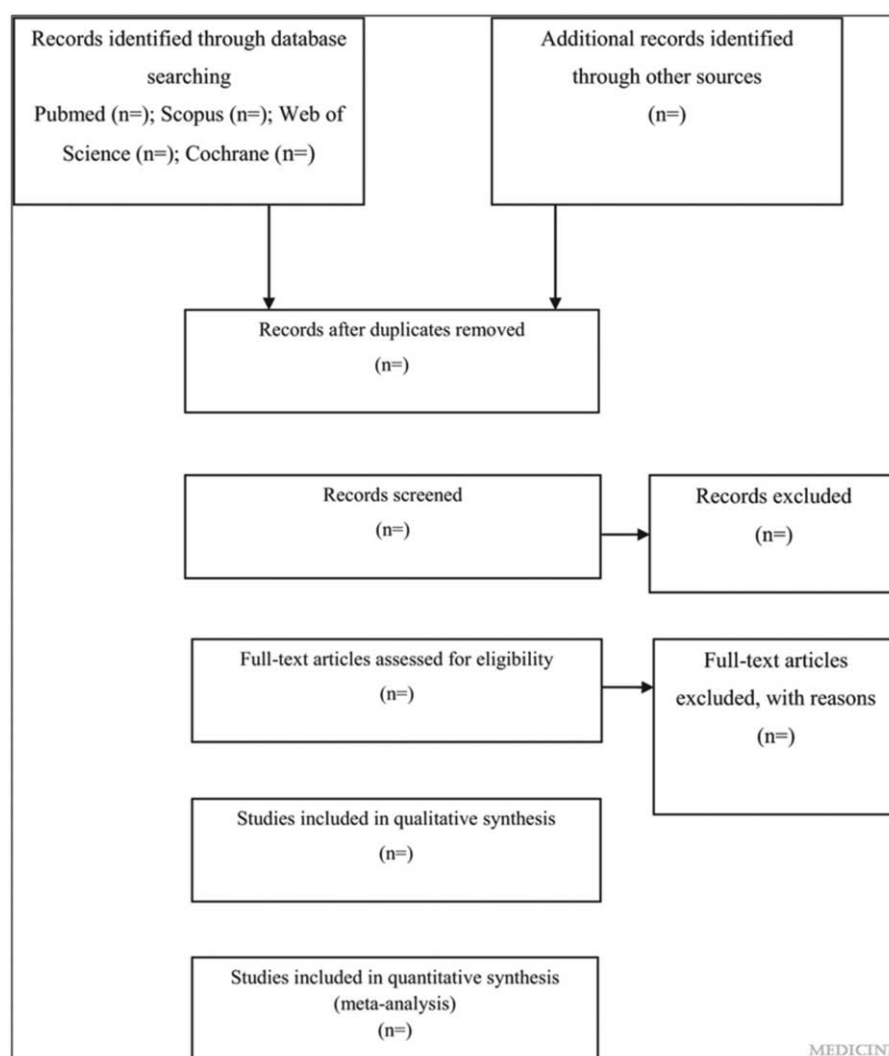


Figure 1. Flow diagram of study selection process.

extraction of data from selected studies (study design, year, country, number of participants, characteristics of volunteers, age, equipment used, exercise performed, treatment of RMS and % MIVC, obtained results and discussion). A second author (FFRB) will check the accuracy and consistency of all entries and make relevant clarifications when necessary. A third author (GCS) will arbitrate unresolved disagreements regarding data extraction.

3.4.4. Assessment of bias quality and risk of included studies. Two independent reviewers will assess bias quality/risk using the Cochrane Handbook of Systematic Reviews of Interventions,^[12] thereby finding consensus through a discussion

or a third party deciding whether no consensus has been reached. Will be checked: missing data, internal consistency of data, integrity of randomization (balance of volunteer characteristics at randomization, randomization pattern), standard of monitoring, and censorship. The summary tables will be verified with the test protocol and evaluation or publication report (Table 3). Any discrepancy or unusual patterns will be verified with the second reviewer of the study.

3.4.5. Data synthesis. The ad hoc tables will demonstrate the summary of the data of the included studies and show their key characteristics and any important issues related to the purpose of this review. The I^2 statistic will be used to evaluate

Table 1

Sample search string for PubMed MEDLINE.

Limits: Language of publications: English and Portuguese (since it was published in English).

Truncation symbol: * = all possible word endings included

Query translation

CIVM (all fields); ou MIVC (all fields); RMS (all fields) ou root mean square (all fields); Rectus Abdominis (all fields); EMG (all fields) ou electromyography (all fields); Strength Exercises (all fields); Abdominal Exercises ou Exercises (all fields);

Table 2**Data extraction variables.**

Data items	Content
Study	Authors; Year of Publication; Country;
No.	Number of participants
Age	Age of the participants
EMG ¹	Details on the muscles analyzed
EMG ²	Details about the volunteers' familiarization (training time) with the proposed exercises
EMG ²	Details about the exercise amplitude during electromyographic signal collection
EMG ³	Details about the muscle activation in different exercises
EMG ⁴	Details about the signal analysis in the temporal domain
EMG ⁵	Results obtained after normalization of the EMG signal by maximal voluntary isometric contraction
EMG ⁶	Details on how the MVIC* was done (manual loading, load cell or other);
Exercises ¹	Which exercises were performed
Exercises ²	What equipment was used

* MVIC = maximal voluntary isometric contraction.

statistical heterogeneity. Quantitative and narrative synthesis will be used to complete the review objective if a meta-analysis is not possible.

3.4.6. Sensitive analysis. A sensitivity analysis will be performed excluding one-to-one analysis studies.

3.4.7. Analysis of subgroups. Will not be performed.

4. Discussion

Previous studies have been published analyzing the muscular activity of exercises proposed for the strengthening of core muscles, however, no review article has been proposed within this theme.^[13–19] The present study will pioneer a centralized analysis of the activation of the abdominal muscles (rectus abdominis) during the execution of different exercises, thus providing a detailed summary of the available evidence. We will conduct and report our review using existing guidelines that will take into account the potential bias risks for each study.^[20]

Electromyography is the gold standard for determining muscle action, so understanding the muscular activation generated by different physical exercises is of great importance for

professionals related to health care, aesthetics and physical performance, since such information allows a reflection on the efficiency and safety of the proposed exercises, as well as important adjustments to an efficient prescription.^[21] This protocol is clear and well structured to maximize the extraction of relevant information, aiming to contribute with scientific information in summary form about the electromyographic activation of the abdominal muscles during the execution of the different physical exercises.

Author contributions

TMF, FFRB, LR, GCS, AG, EPC, CP, EGH, GGA, FCG, FCRG, FJA, LAS, AAP, HKMA, GMP, and FBL conceived the study idea and devised the study methodology. LR, TMF, and FBL participated in the design and coordination of the study. TMF was primarily responsible for protocol writing and developed the search strategy. LR and TMF will screen identified literature, conduct data extraction and analyses the review findings. All authors read the drafts, provided comments and agreed on the final version of the manuscript.

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Table 3**List of quality assessment of cross-sectional and longitudinal studies.**

Item	Score*	Design†
Selection of the population in relation to health status.	+ = Yes, – = No, ? = Unsure	Lg/Cr
Main characteristics of the study population.	+ = Yes, – = No, ? = Unsure	Lg/Cr
Specific purpose clearly stated	+ = Yes, – = No, ? = Unsure	Lg/Cr
Intensity of the activation of the abdominal muscles during the execution of the exercise.	+ = Yes, – = No, ? = Unsure	Lg/Cr
Methodological criteria adopted in the different studies to investigate the electromyography of the abdominal muscles	+ = Yes, – = No, ? = Unsure	Lg/Cr
Results obtained after EMG analysis	+ = Yes, – = No, ? = Unsure	Lg/Cr

* Maximum score: 10 for longitudinal studies, 8 for cross-sectional studies.

† This column shows whether the item was used in cross-sectional (Cr) or longitudinal (Lg) studies.

References

- [1] Di Dio Ija. *Treaty of Applied Systemic Anatomy 1 and 2*. 2nd edn. São Paulo: Atheneu; 2002.
- [2] Weineck J. *Anatomy Applied to Sports*. 18th edn. São Paulo: Manole; 2013.
- [3] Vaz MA, Bercht V, Trombini RS, et al. Comparison of the intensity of electrical activity of the rectus abdominis and external oblique muscles in abdominal exercises with and without the use of devices. 1999. Florianópolis.
- [4] Kim MH, Oh JS. Effects of performing an abdominal hollowing exercise on trunk muscle activity during curl-up exercise on an unstable surface. *J Phys Ther Sci* 2015;27:501–3.
- [5] Azuma K, Sera Y, Shinjo T, et al. Maintenance of the paraspinal muscles may protect against radiographic knee osteoarthritis. *Open Access Rheumatol* 2017;9:151–8.
- [6] Bompa TO, Cornacchia LJ. *Conscious Strength Training*. São Paulo: Manole; 2000.
- [7] Konrad P. *The ABC of EMG: a practical introduction to kinesiological electromyography* Boston Noraxon EMG and Sensor Systems, 2005.
- [8] Martuscello JM, Nuzzo JL, Ashley CD, et al. Systematic review of core muscles activity during physical fitness exercises. *J Strength Cond Res* 2013;27:1684–98.
- [9] Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002;21:1539–58.
- [10] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009;339.
- [11] Shamseer L, Moher D, Clarke M, et al. PRISMA-P Group Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ* 2015;349:g7647.
- [12] Higgins J, Green GS. *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0. The Cochrane Collaboration; 2011; updated March 2011.
- [13] Benjami DR, Water ATM, Peiris CL. Effects of exercise on diastasis of the rectus abdominis muscle in the antenatal and postnatal periods: a systematic review. *Physiotherapy* 2014;100:1–8.
- [14] Bo K, Morkved S, Frawley H, et al. Evidence for benefit of transversus abdominis training alone or in combination with pelvic floor muscle training to treat female urinary incontinence: a systematic review. *NeuroUrol Urodyn* 2009;28:368–73.
- [15] Ghamkhar L, Kahlaee AH. Trunk muscles activation pattern during walking in subjects with and without chronic low back pain: a systematic review. *PM&R* 2015;7:519–26.
- [16] Granacher UR, Gollhofer A, Hortobágyi T, et al. The importance of trunk muscle strength for balance, functional performance, and fall prevention in seniors: a systematic review. *Sports Med* 2013;43:627–41.
- [17] Laird RA, Kent P, Keating JL. Modifying patterns of movement in people with low back pain—does it help? A systematic review. *BMC Musculoskelet Disord* 2012;13:169.
- [18] Neumann PB, Grimmer KA, Deenadayalan Y. Pelvic floor muscle training and adjunctive therapies for the treatment of stress urinary incontinence in women: a systematic review. *BMC Woman's Health* 2006;6:11.
- [19] Wells C, Kolt GS, Bialocerkowski A. Defining pilates exercise: a systematic review. *Complement Ther Med* 2012;20:253–62.
- [20] Landis J, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.
- [21] Escamilla RF, McTaggart MSC, Fricklas EJ, et al. An electromyographic analysis of commercial and common abdominal exercises: implications for rehabilitation and training. *J Orthop Sports Phys* 2006;36:48–57.